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16. Abstract <p>The objectives of this project are to determine the feasibility of studying surface circulation in coastal waters using surface visible properties observed from ERTS-1 imagery and to study surface water circulation in the Prince William Sound region. To accomplish these, circulation patterns deduced from oceanographic data are correlated with features seen on the ERTS imagery.</p> <p>Results suggest that sediment-laden plumes of fresh water from rivers may be useful tracers, due to their high visibility, of surface water motion. The two useable images obtained to date corroborate that westerly flow was occurring in the Gulf of Alaska just south of Prince William Sound, and that an inflow into Prince William Sound was occurring concurrently with flood tides on both occasions. In conclusion, river plumes are useful tracers, but poor weather conditions somewhat limit the use of satellite imagery.</p> <p>It is recommended that a thermal IR band and more frequent passes be features of future satellites used for this purpose.</p>			
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## I - INTRODUCTION

This report summarizes the work performed and conclusions reached during the first six months of contract no. NAS5-21833, ERTS-1 project no. 110-9, The circulation of Prince William Sound.

During the first six months of this project, ERTS-1 imagery has been received covering the time period 2 August through 3 November 1972. In addition, air photos and IR scanner results from a July 1972 NASA aircraft flight over the study area have been received. All data have been screened to determine which scenes are useful to the project. Only two of the ERTS scenes were useable, the remainder containing excessive cloud cover over the study region. All of the aircraft data were useable but predate the ERTS data sufficiently so that a direct comparison was impossible.

Ground truth data in the form of oceanographic temperature and salinity measurements have been obtained during September and December 1972. These are presently undergoing analysis designed to determine the general circulation patterns in the study region. Due to winter darkness, only the September oceanographic data will be comparable with ERTS data; the satellite was not obtaining data during December.

The useable ERTS images have been contrast enhanced to produce black and white prints showing maximum detail over the water areas. In addition, 3M color-keyed composites have been made in an attempt to compile all information onto a single copy. Visual examination of these products and of the aircraft data suggest that river sediment plumes are useful tracers for surface water motion, as they retain their identities over large distances and are highly visible in the visible wavelengths (MSS bands 4 and 5). The aircraft data indicate, moreover, that the sediment laden river water is of lower temperature than the marine waters; a fact borne out by the oceanographic data.

Work during the initial 6 month phase of this project has been sufficient in general for finalization of the data handling and analysis plan. Additional satellite data are needed, however, for formulation of conclusions concerning circulation in the study area, due to the poor initial image quality due to excessive cloud cover.

## II - STATUS OF PROJECT

### A. Objectives

Overall objectives of the project are to test the feasibility of investigating the surface circulation of coastal waters using distribution of a purely visible surface parameter as derived from ERTS imagery and, in the event that such feasibility is positively determined, to study the surface circulation of the Prince William Sound, Alaska region. The objectives of the initial 6 month phase of the project have been to, firstly, finalize plans for data handling and analysis and, secondly, to receive, screen and analyze ERTS and NASA aircraft imagery. Both objectives of the initial project phase have been met and it has been determined, through visual analysis of the ERTS and aircraft data, that river sediment plumes

may serve as tracers in studying surface water circulation. This objective is critical to the second major overall project objective, which is to study the surface circulation in the study region.

## B. Accomplishments During the Reporting Period

### 1. Preliminary Investigations

Oceanographic investigations have been carried out in the Prince William Sound region since May 1971. Although these were not carried out expressly for use by this project, they have provided a backlog of information useful to the project. While data collected in 1971 were geographically too scattered to be of much use, a detailed series of observations made in March 1972 provided sufficient information to guess at the water circulation patterns there. An additional detailed set of observations obtained in June 1972 added to this.

Oceanographic data collected in conjunction with acquisition of ERTS data included temperature and salinity data collected during September and December 1972 and January 1973. Data from the first of these have been processed to put them into useable format and are now being analyzed by construction and visible examination of, e.g., vertical cross-sections of temperature and salinity and temperature-salinity diagrams. Data from the December cruise are in the final processing stages, while data from the January cruise are in the initial processing stages. Unfortunately, due to low ambient light levels, no ERTS data were collected coincident with the December and January cruises, precluding a comparison of ERTS and ground truth data.

The Principal Investigator for this project participated in a NASA aircraft flight over the study region, during July 1972, during which data were acquired in the visible, near-infrared and thermal infrared bands. These data have been acquired, screened and analyzed. They provided a preliminary indication that river sediment plumes might be useful in tracing surface currents. Sediment patterns within Port Valdez reflected a cyclonic circulation there which had been deduced from earlier oceanographic measurements in the region. The thermal infrared bands indicated a strong correlation between low temperature surface water and sediment-laden water, in agreement with earlier oceanographic baseline data. The near-infrared bands showed effectively the same picture as the visible bands, but effectively screened out some low-level atmospheric haze which was present during the observations. The aircraft data suggested, in general, that river-derived sediment plumes would be a prerequisite for ERTS data to be useful in meeting the project objectives. The temperature differences evident on the thermal infrared bands would not be evident on the ERTS bands. It was also evident from the aircraft data that a minimal cloud cover would obscure the water surface appearance to the point where images in the visible became useless. Images in the near-infrared, while they penetrated light haze, did not provide the detail in the water that the visible images did under clear conditions. It was suspected at this point that foul weather typical of the study region might prove a limiting factor in the usefulness of satellite imagery in such a region.

## 2. Applicability of ERTS-1 data to project objectives

In order to be of use to the project, ERTS images must have: (1) light enough cloud cover so that there is no chance of confusing the cloud cover with the surface appearance of the water, or of having the water surface completely obscured by clouds; and (2) a source of sediment-laden water to serve as a tracer of surface motion. Of course, the images must also be of the proper geographical region. Only two ERTS images have been received, to date, which have met both of these requirements; ERTS scenes 1064-20282 and 1081-20284. All other images received, though they had less than the specified 80% cloud cover, had either total cloud cover over the visible water area or sufficient light cloud cover so that it was impossible to make out the surface appearance of the water. Both of the viable images showed the same region; a rectangle including the portion of the Gulf of Alaska from Middleton Island to Cape St. Elias to Hinchinbrook Entrance, and the southeast portion of Prince William Sound.

In order to fully utilize the ERTS data, it is necessary to have black and white prints custom-made from the high-density 70 mm negative transparencies supplied by NASA. These prints are made in such a way as to enhance the appearance of the water surface at the expense of land surface appearance. These prints have revealed that most information on the water surface is contained in MSS bands 4 and 5; this is due to the fact that light in the near-infrared bands 6 and 7 has little ability to penetrate water relative to light in bands 4 and 5 (blue and red). Bands 6 and 7 are useful in delineating the exact shoreline, however, in cases where the water is so turbid as to make the shoreline invisible on bands 4 or 5.

Color overlays have been made, for ERTS scene 1081-20284, using the 3M color-key process in an attempt to compile all information from the different bands onto a single image. In light of the relatively high cost of this process, coupled with the fact that most information is contained in bands 4 and 5, it was decided to discontinue this method. The results did not show appreciably more than bands 4 or 5 taken separately although they were, admittedly, more impressive for display purposes.

Both of the useable ERTS scenes obtained show sediment plumes from the Bering Glacier and the Copper River as highly visible features on bands 4 and 5. These plumes are bounded by a well defined shade change of about 2 shade units on band 4, and extend 5-10 miles offshore, following the known westerly circulation in the northern Gulf of Alaska. Both scenes indicate that inflow was occurring into Prince William Sound at the time of the satellite pass, but both scenes were viewed during a flood tide so this would be expected. It was necessary for both scenes to utilize band 7 in order to determine boundaries between the dense sediment plumes and mud flats, barrier islands and beaches in the inshore regions. Bands 4, 5 and to an extent 6 showed all these features as identical; only band 7, with its inability to penetrate water, showed the water as black and the land features in shades of grey. It was possible, finally, to determine the direction from which swell was coming in the Gulf of Alaska on any of the ERTS bands from scene 1081-20284. The surf zone showed as a well-defined white band on the southeastern boundaries of coastal features, in agreement with a southeasterly wind which had been blowing over the Gulf for several days preceding acquisition of the images.

Validity of the conclusions drawn using the ERTS data depend upon the availability of baseline oceanographic data from the region. Information from these oceanographic data determine to what extent features seen on the ERTS data are representative of physical processes. As an example, data from tide tables were necessary to determine that both of the above ERTS images were obtained during flood tide. Were this not known, it would have been possible to erroneously conclude that a net, non-tidal circulation was occurring into Prince William Sound. Past data were responsible for the knowledge that net circulation in the northern Gulf of Alaska is westerly; ERTS data are useful in that they appear to provide a positive corroboration of this fact, which has been derived from only scattered oceanographic data. Meteorological data (obtained from the U.S. Weather Bureau) indicated that a southeasterly wind had preceded the presence of swell from that direction, suggesting that ERTS data may, in fact, be used to study direction from which heavy seas come in a given region. General regional hydrological knowledge indicates that the Copper River was at a low level of flow during time of image acquisition, so that a more fully developed plume may be expected next spring, with concurrently greater information gathering hopefully being possible.

While no useable ERTS data have been obtained for Prince William Sound proper, the above arguments apply equally well to that body of water. Knowledge of tides and of annual cycles of river runoff will be particularly important, and are available as tide tables and collected general knowledge of the region. Whereas the westerly circulation in the Gulf of Alaska was known via past oceanographic data, so the net circulation within Prince William Sound is yet to be definitively determined; for this purpose, collection of oceanographic data is a continuing effort.

The aircraft data obtained during July 1972 were useful to the overall ERTS project. They consisted of visible, near-infrared and thermal infrared scanner data from the eastern Prince William Sound and Port Valdez regions. Data from the latter region were obtained from 5,000 ft and were therefore considerably more detailed than those from Prince William Sound. The circulation patterns within Port Valdez were known as a consequence of past oceanographic research there, and it was possible to correlate the river sediment plumes originating at the head and near the mouth of Port Valdez with these patterns, thus further substantiating that sediment plumes were viable indicators of circulation, in this case on a relatively small size scale. Comparison of the visible and near-infrared data indicated that the former yielded more detail in the water structure, while the latter was able to penetrate light haze in the atmosphere and therefore better define actual surface features. The thermal infrared scanner data indicated that the sediment-laden water was also of a low temperature relative to the ambient marine waters. This is in agreement with conclusions drawn from the oceanographic data and was a consequence of the fact that river water is of lower temperature than marine water at this time of year (July). These conditions might well not prevail at other times of year, e.g., autumn.

The aircraft data indicated that, given no cloud cover, ERTS data should yield information on the circulation within Port Valdez due to the presence there of ample sediment-laden river water. Port Valdez is of particular interest due to the proposed construction there of a southern terminus for the Trans-Alaska oil pipeline. Oceanographic data are being acquired from Port Valdez as well as from Prince William Sound proper.

### 3. Results

Due to the small number of useable ERTS images received (2) and the fact that both of these were biased in that they were obtained during a flood tide, it is impossible to draw any conclusions concerning circulation of water in the study area. It is only possible to state that these scenes substantiate the known flow pattern in the northern Gulf of Alaska, i.e., a westerly flow just south of Prince William Sound. More positive are the results that river sediment plumes appear to constitute useful tracers for surface water motion, as determined from both the ERTS and the aircraft data. It appears to be possible, in addition, to determine the direction of swell direction by location of the surf zone on ERTS images. The aircraft data from Port Valdez suggest that it is possible to detect small-scale (on the order of several meters) turbulent eddies in the water by noting the sediment patterns. These are too small, however, for detection from ERTS, and they do not lend themselves to quantitative analysis.

The lack of results to date should not be discouraging. The ERTS data have been obtained during the period of the year characterized by the worst weather, followed directly by a period when light levels are too low to obtain any data at all. It is anticipated that ERTS data obtained during spring and summer 1973, when cloud cover is historically less over the study region and seasonally high river runoff will result in better-defined plumes, will provide considerably greater information content than to date.

### III - NEW TECHNOLOGY

No new technology has been derived from this project.

### IV - PLANS FOR NEXT REPORTING PERIOD

Acquisition of ERTS data in the study region will not recommence, due to low winter light levels, until 16 February 1973. Since a minimum lag of one month is typical before data are received by this project, it is not anticipated that additional ERTS data will be received prior to mid-March 1973. It is therefore not anticipated that any additional handling and analysis of ERTS data will occur during the next two-month reporting period. Analysis and processing of the oceanographic ground truth data will continue, however, through this reporting period. In addition, an oceanographic cruise into the study region to obtain additional data will be carried out on 8-9 March, and processing and analysis of the data therefrom will be initiated.

The next 6 month reporting period will be utilized to acquire, screen, process as required and analyze ERTS data. An oceanographic cruise to the study region, to obtain additional ground-truth data, is planned for May 1973. Processing and analysis of the oceanographic data will proceed concurrently with that of the ERTS data. As information becomes available in suitable form, comparisons will be made and conclusions drawn using all available data; both ERTS and oceanographic. Meaningful comparisons will be prepared in a format wherein sediment distributions are plotted on a chart along with circulation deduced from the oceanographic data. It is hoped that ERTS data will allow the filling of temporal data gaps between oceanographic cruises to the study area.

## V - CONCLUSIONS

A major conclusion to date is that suspended sediment plumes originating from rivers appear to provide suitable tracers for surface water circulation. These are useable to a greater or lesser degree, depending upon the horizontal distances over which they retain their visible (from ERTS) identity and upon the regional cloud cover at the time of the satellite overpass. A secondary conclusion is that ERTS data may be useful in determining the direction from which waves or swell are impinging upon a coastline.

Negative conclusions are the drastic effect that even light cloud cover has in reducing the utility of the ERTS data in this study. It becomes impossible, under conditions of light cloud cover, to separate the clouds from variations in the water surface appearance. The relatively high cloud cover in the study region during the autumn period, coupled with winter darkness, has resulted in very few useable ERTS images being obtained by this project. Consequently, it is impossible to date to draw any conclusions concerning the circulation within the study area; Prince William Sound.

Corroboration of westerly surface flow in the Gulf of Alaska suggests that ERTS data are indeed useful for oceanographic research by providing information pertinent to circulation patterns during periods when oceanographic data are not being obtained from the region. Such information can be used to strengthen a case based purely upon oceanographic evidence.

## VI - RECOMMENDATIONS

Due to the positive conclusions concerning utility of ERTS in studying surface circulation, this principal investigator intends to continue the present study using data from ERTS-B. This would be carried out in conjunction with projected oceanographic studies in the Prince William Sound region.

While it is recognized that the sensor complement of ERTS-B is already fixed, it is recommended that any future environmental satellite carry a thermal infrared scanner. It is felt that data from such a device would be invaluable in oceanographic investigations in near-shore waters, particularly if the resolution approached that of the multispectral scanners. It would be useful, also, if the data were obtained from a given area more frequently than once every 18 days. Oceanographic processes may occur over a considerably shorter time period, and such short-term variations would be invisible to a satellite passing over every 18 days. More frequent coverage would, in addition, provide more numerous useable images in a region such as the present study area characterized by high cloud cover.

Finally, it is felt that a disproportionate amount of time spent on this project has been spent on paperwork. Since other funding agencies appear to do quite well without it, and much of it has been rather meaningless, it is suggested that the paperwork requirements on principal investigators of ERTS projects be radically reduced.



VII - PUBLICATIONS

None.

VIII - REFERENCES

None.

#### APPENDIX A - CHANGE IN STANDING ORDER FORMS

No changes have been made in standing order forms.

#### APPENDIX B - ERTS DATA REQUEST FORMS

Data request forms were sent to NASA, in mid-January, requesting ERTS scenes 1100-20342, 1100-20344, 1101-20400, 1101-20403, 1102-20455 and 1102-20461. These scenes were never received, although they had been requested previously.

## APPENDIX C

PRINCIPAL INVESTIGATOR Robin D. Muench

GSFC UN 614

ORGANIZATION IMS University of Alaska

**D** \_\_\_\_\_

**N** Nonlinear

ID \_\_\_\_\_

PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
	clouds	mtns.	rivers	
1047-20392 M	X	X	X	
1047-20395 M	X			
1103-20513 M		X	X	glaciers; oceans
1102-20461 M		X		glaciers; oceans
1102-20455 M		X	X	glaciers; oceans

\*FOR DESCRIPTORS WHICH WILL OCCUR FREQUENTLY, WRITE THE DESCRIPTOR TERMS IN THESE COLUMN HEADING SPACES NOW AND USE A CHECK (✓) MARK IN THE APPROPRIATE PRODUCT ID LINES. (FOR OTHER DESCRIPTORS, WRITE THE TERM UNDER THE DESCRIPTORS COLUMN).

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#### APPENDIX D - SIGNIFICANT RESULTS

Due to the fact that no additional ERTS data of useable quality have been received during the last two month (December-January) reporting period, there are no new significant results to report for that period. Processing and analysis of the December and January oceanographic data have not yet progressed to the point where it is possible to make conclusions from these.